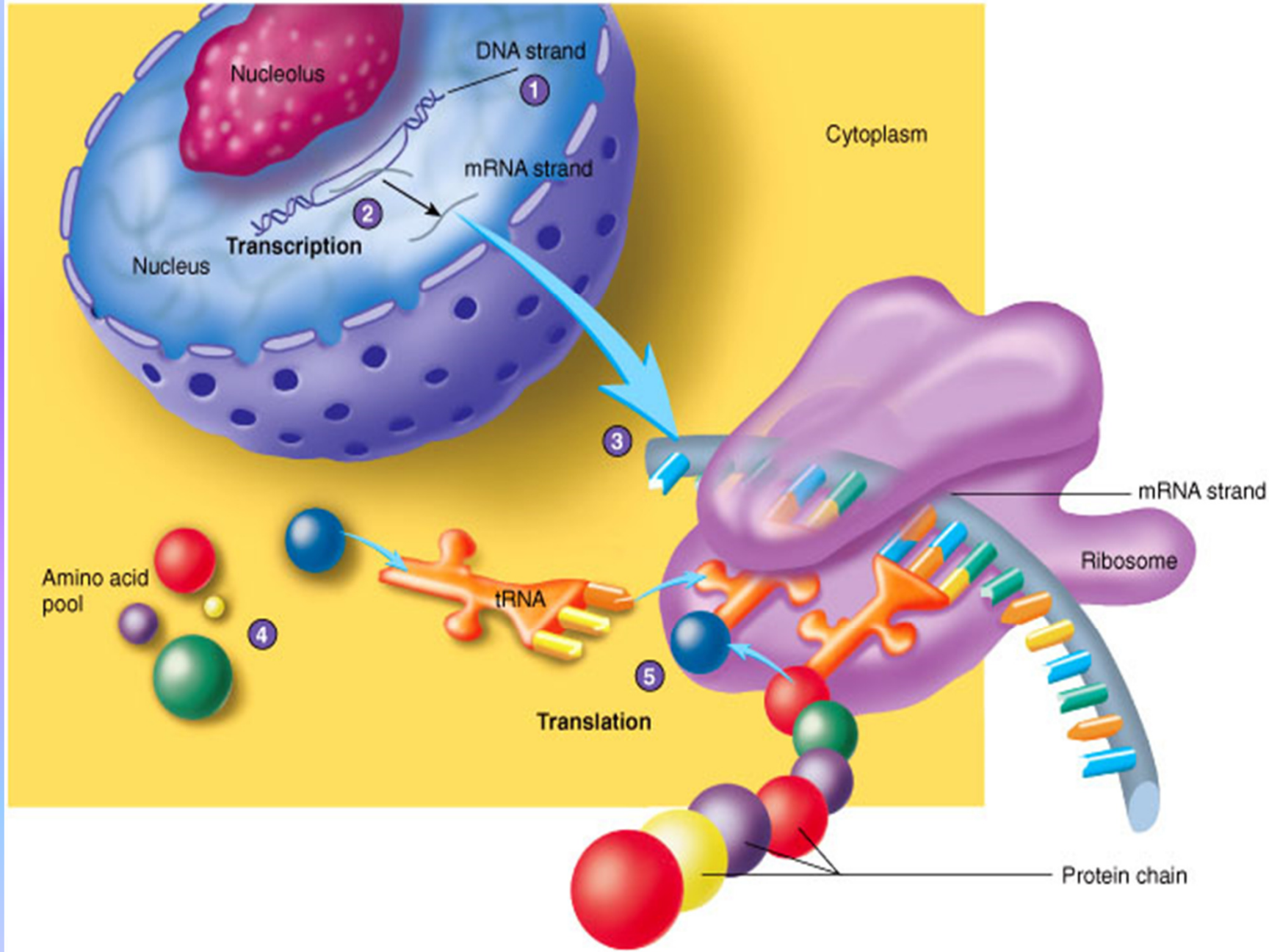
Gene Action: From DNA to Protein

- ***Genome*** =
  - The complete set of genetic instructions in the cells of a particular type of organism
- ***Exome*** =
  - The part of the genome that encodes protein
- ***Gene*** =
  - Sequence of nucleotides in DNA that is a chemical set of instructions for making a specific protein

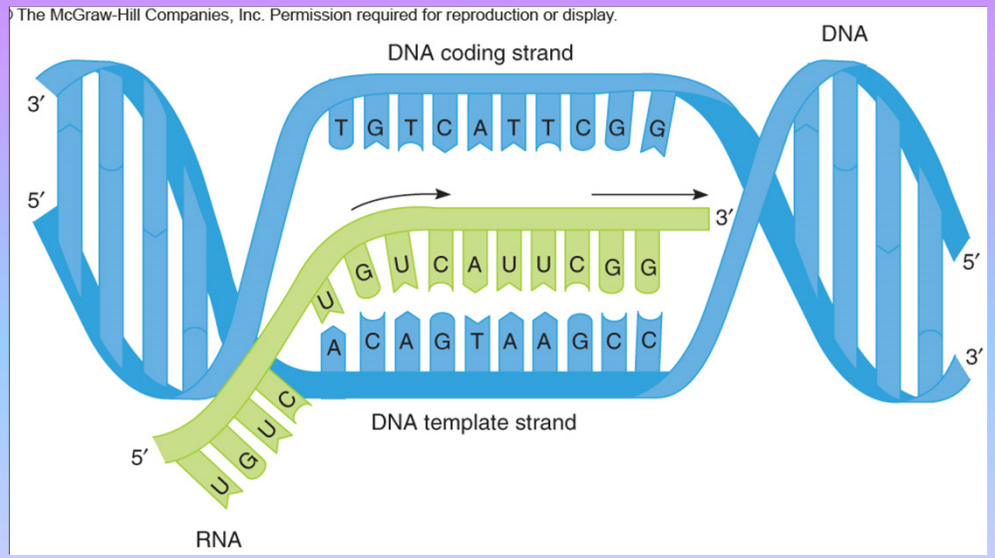
Protein Synthesis

- ***Transcription*** =
  - Manufacturing RNA from DNA
  - In nucleus
- ***Translation*** =
  - Assembly of an amino acid chain to make a protein according to the sequence of base triplets in a molecule of mRNA
  - RNA to protein
  - In cytoplasm at ribosomes



Transcription

- RNA is the bridge between gene and protein
- ***RNA polymerase*** (enzyme) adds RNA nucleotides to a growing RNA chain
  - Complementary to ***template strand*** of DNA's double helix
  - Identical to ***coding strand*** (except for uracil)



DNA

- Double stranded
- Thymine
- Sugar is Deoxyribose

RNA

- Single stranded
- Uracil
- Sugar is Ribose

- Types of RNA
  1. Messenger RNA (mRNA)
     - Carries genetic information from DNA to ribosomes
  2. Ribosomal RNA (rRNA)
     - Important component of ribosomes
  3. Transfer RNA (tRNA)
     - Carries amino acids to ribosomes during the assembly of proteins

rRNA

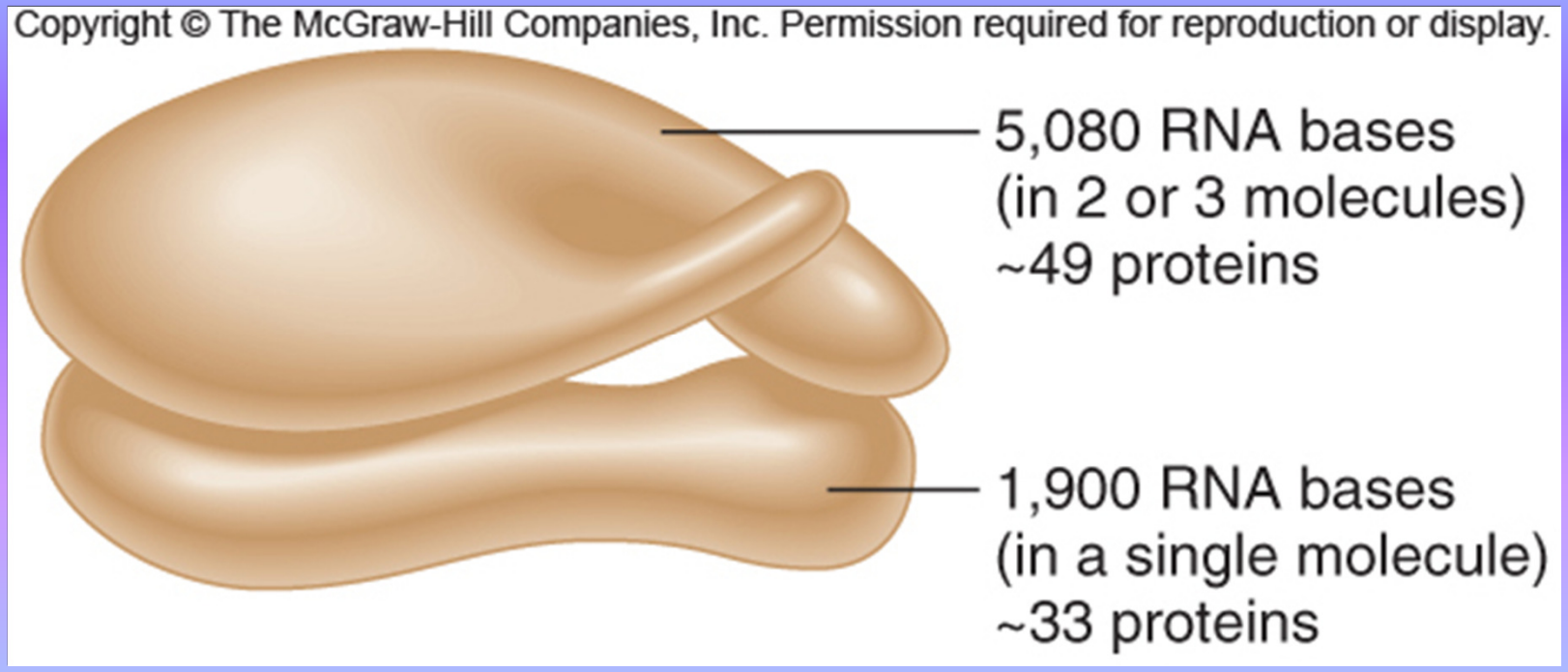


Figure 10.4

Figure 10.5

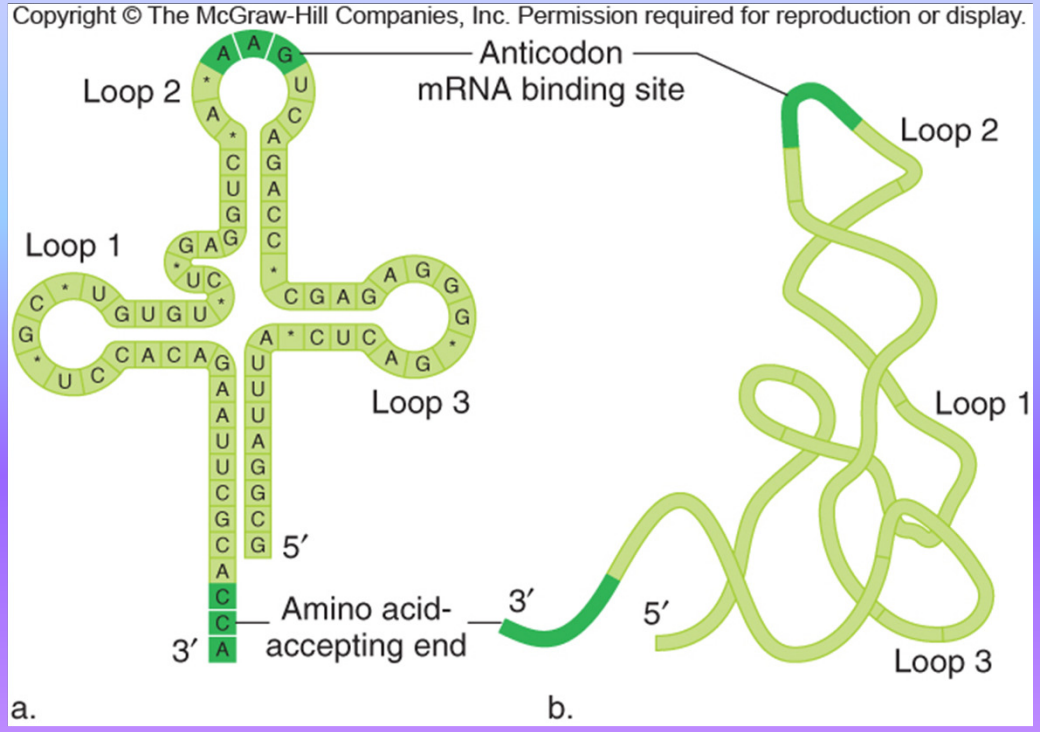
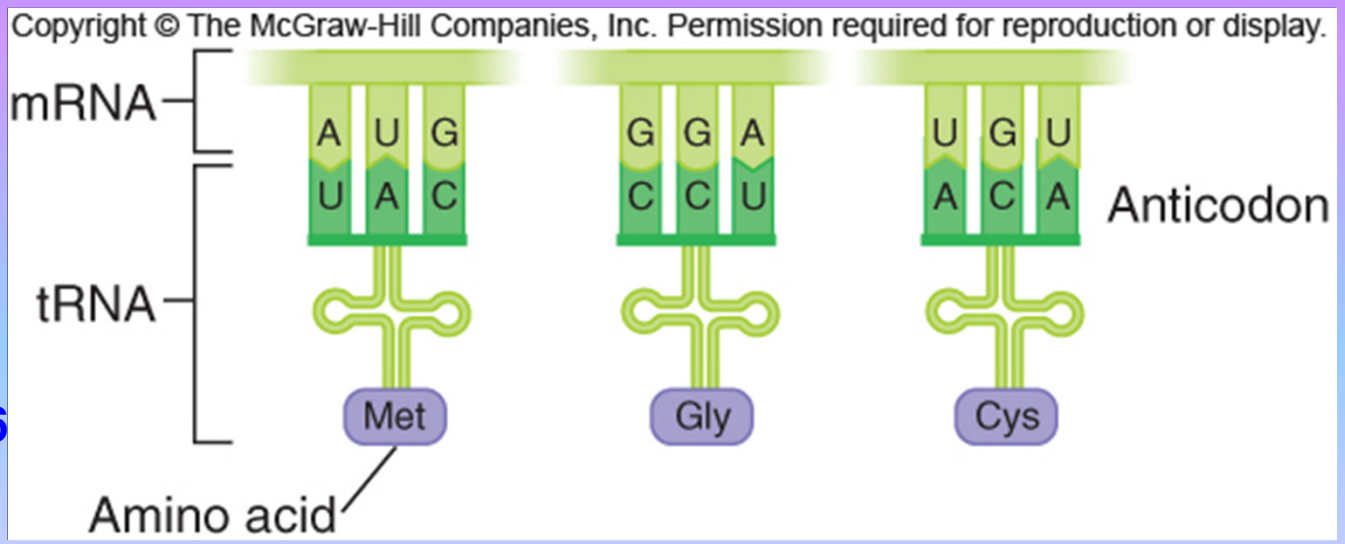


Figure 10.6

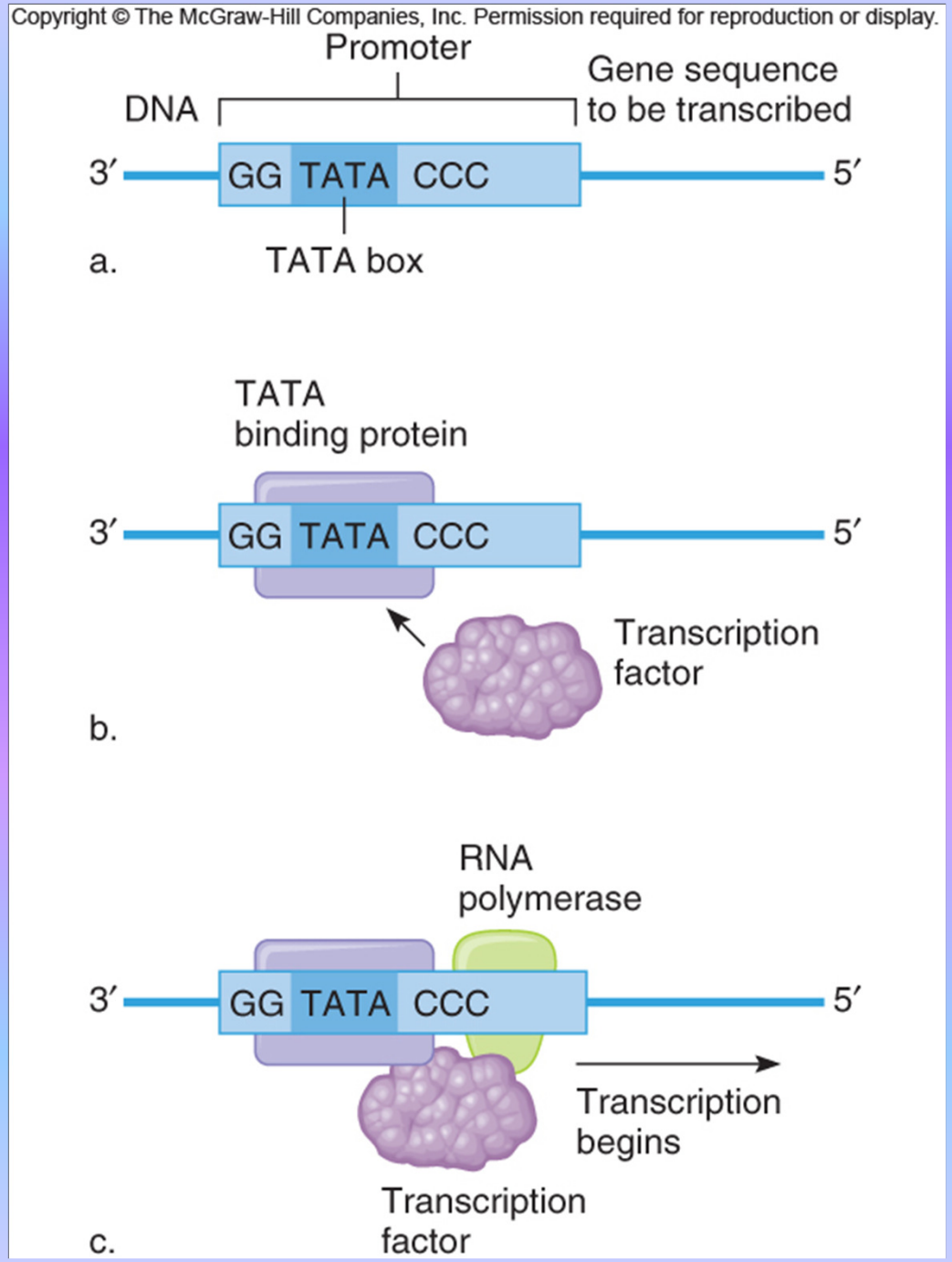


- ***Transcription factors*** =
  - Proteins that activate the transcription of certain genes

- Steps of Transcription

1. Transcription initiation
   - Transcription factors and RNA polymerase are attracted to a ***promoter*** =
     - Control sequence near the start of a gene
     - Composed of a DNA sequence called a TATA box
       - Base sequence TATA surrounded by long stretches of G and C

Figure 10.7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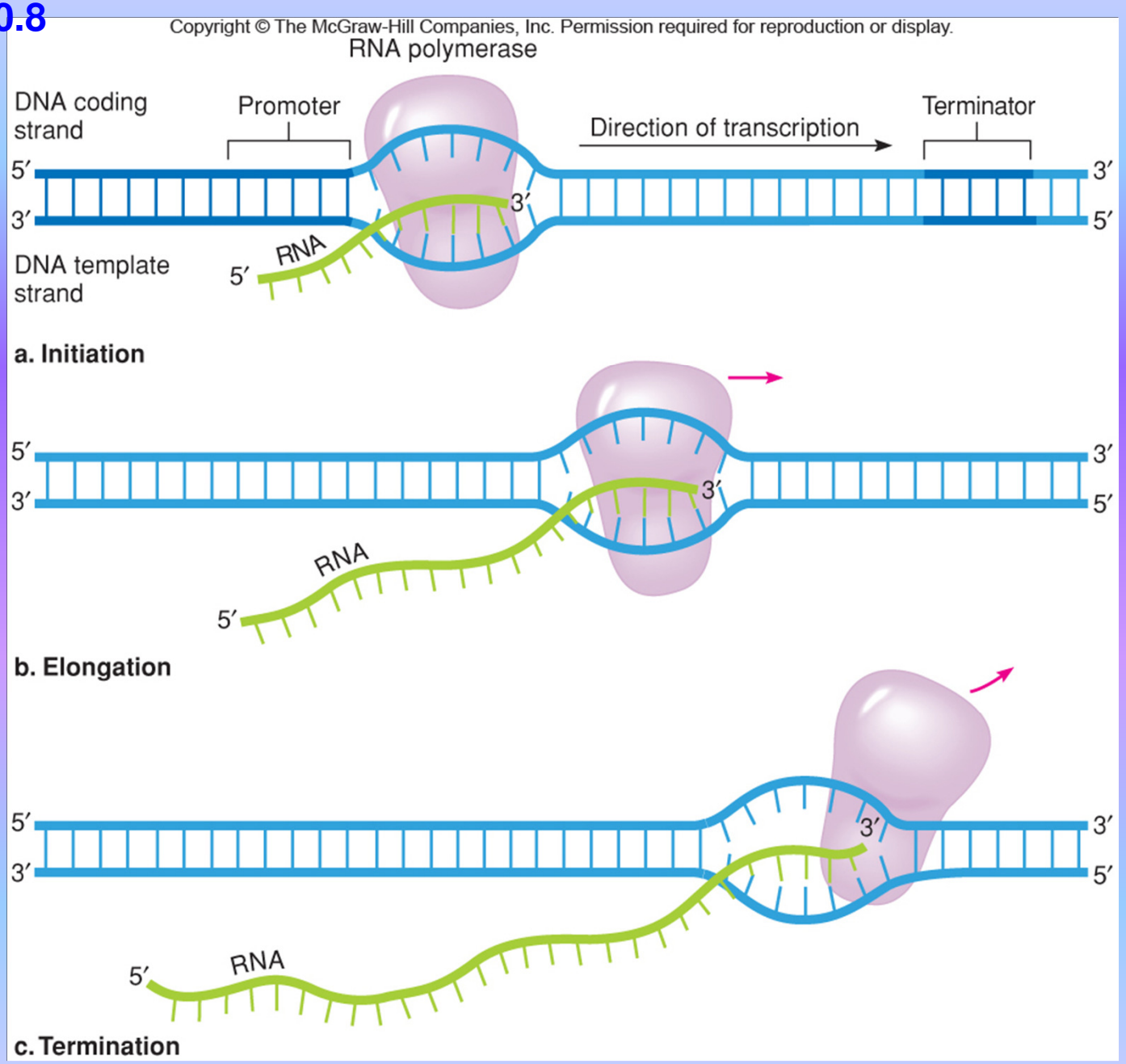
Promoter
DNA
Gene sequence to be transcribed
3′
GG TATA CCC
5′
TATA box
a.
TATA binding protein
3′
GG TATA CCC
5′
Transcription factor
b.
RNA polymerase
3′
GG TATA CCC
5′
Transcription begins
Transcription factor
c.

2. Transcription elongation
   - Enzymes unwind the DNA double helix locally
   - Free RNA nucleotides bond with exposed complementary bases on DNA template strand
     - RNA's **C** bonds with DNA's **G**
     - RNA's **G** bonds with DNA's **C**
     - RNA's **A** bonds with DNA's **T**
     - *RNA's **U** bonds with DNA's **A***
   - Synthesized in 5' to 3' direction

3. Transcription termination
   - Termination sequence in the DNA indicates where the gene's RNA-encoding region ends

Figure 10.8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RNA polymerase
DNA coding strand
Promoter
Direction of transcription
Terminator
5′
3′
3′
5′
3′
RNA
5′
DNA template strand
a. Initiation
5′
3′
3′
5′
3′
RNA
5′
b. Elongation
5′
3′
3′
3′
5′
5′
RNA
c. Termination

Let's Practice!

- DNA template strand

C C T A G C T A C

- RNA

G G A U C G A U G

- DNA coding strand

G G A T C G A T G

- RNA Processing (after transcription)
  - Cap is added to 5’ end
    - Recognition site for protein synthesis
  - Poly A tail is added to 3’ end
    - Necessary for protein synthesis to begin
    - May also stabilize mRNA so it stays intact longer
  - ***Introns*** are removed
    - Part of a gene that is transcribed but is excised from the mRNA before translation into a protein
  - Ends of remaining molecule are spliced together
  - The parts of mRNA that remain and are translated are called ***exons***
    - The part of a gene that encodes amino acids
  - Mature mRNA exits the nucleus to be translated

Figure 10.10

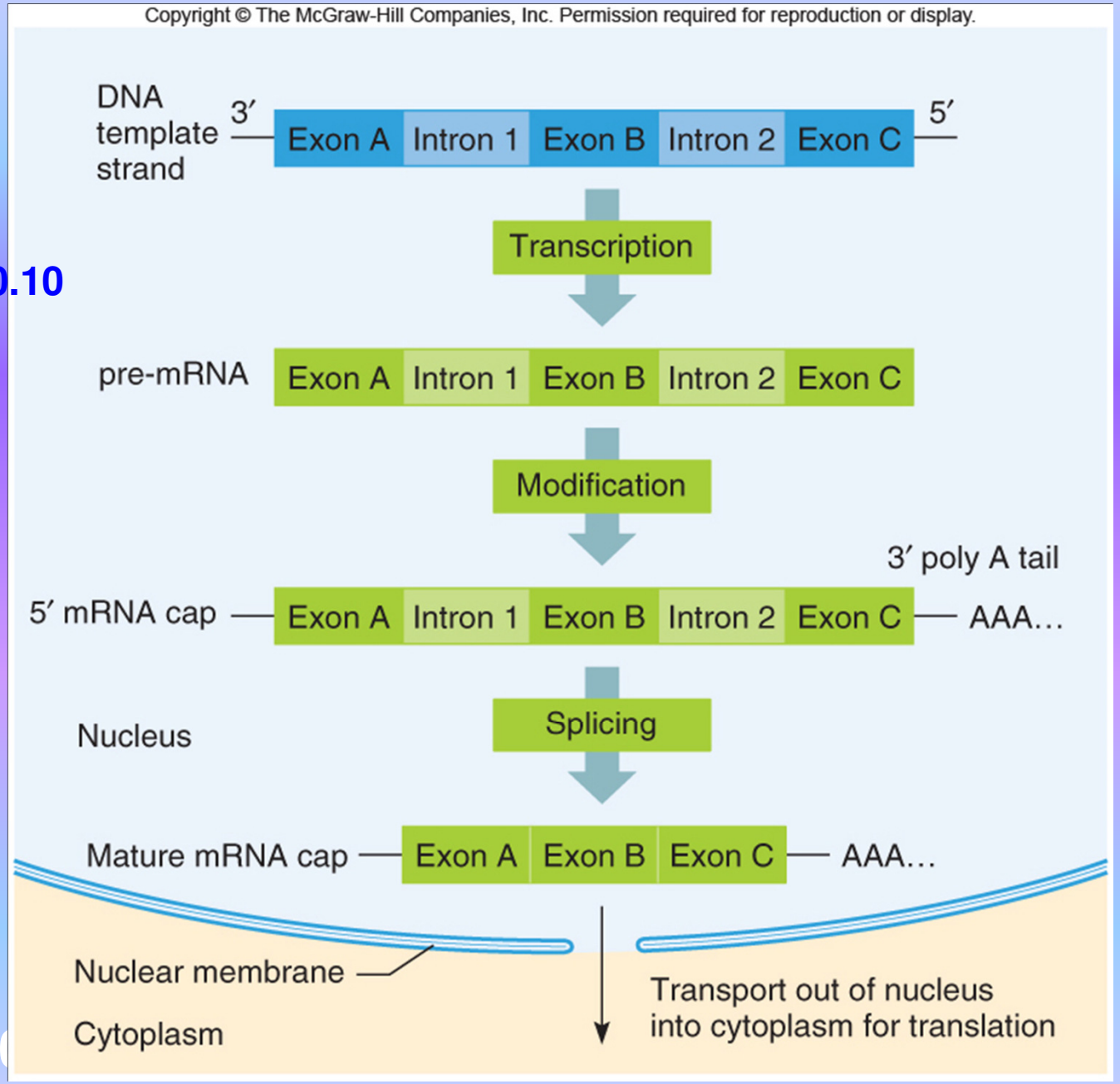
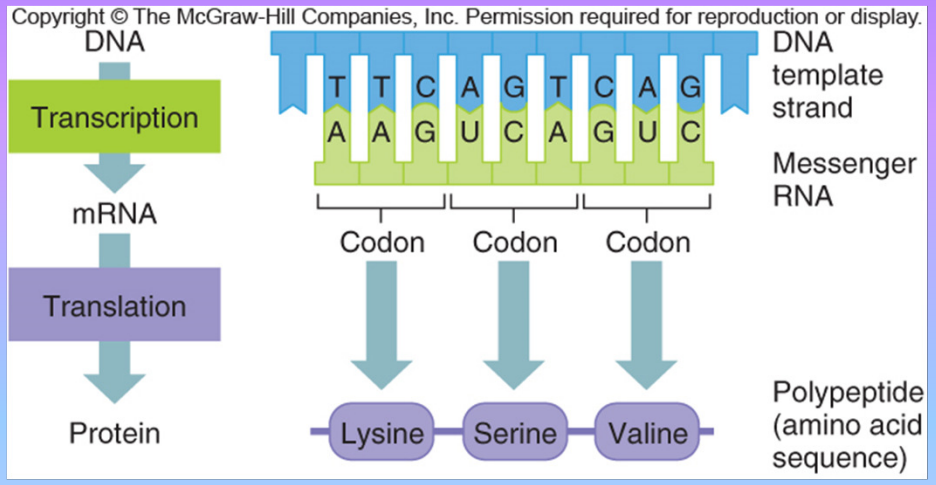


Figure 10

Translation

- ***Genetic code*** =
  - Correspondence between specific mRNA triplets and the amino acids they specify
  - The genetic code is
    1. Triplet
    2. Nonoverlapping
    3. Continuous
    4. Universal
    5. Degenerate



Deciphering the Genetic Code

1. Triplet

- ***Codon*** =
  - Continuous triplet of mRNA that specifies a particular amino acid
- ***Reading frame*** =
  - Sequence of amino acids encoded from a certain starting point in the DNA sequence
  - Disrupted when the DNA sequence is altered by one or two bases, producing a different amino acid sequence

2. Nonoverlapping

- 9 bases = 3 codons = 3 specific amino acids
- But DNA sequence can be read in 3 different reading frames, depending on the “start” base

3. Continuous

- Some codons do not code for amino acids but perform other functions
  - AUG is the “start” codon
  - UGA, UAA, and UAG are “stop” codons

4. Universal

- All species use the same mRNA codons to specify the same amino acids

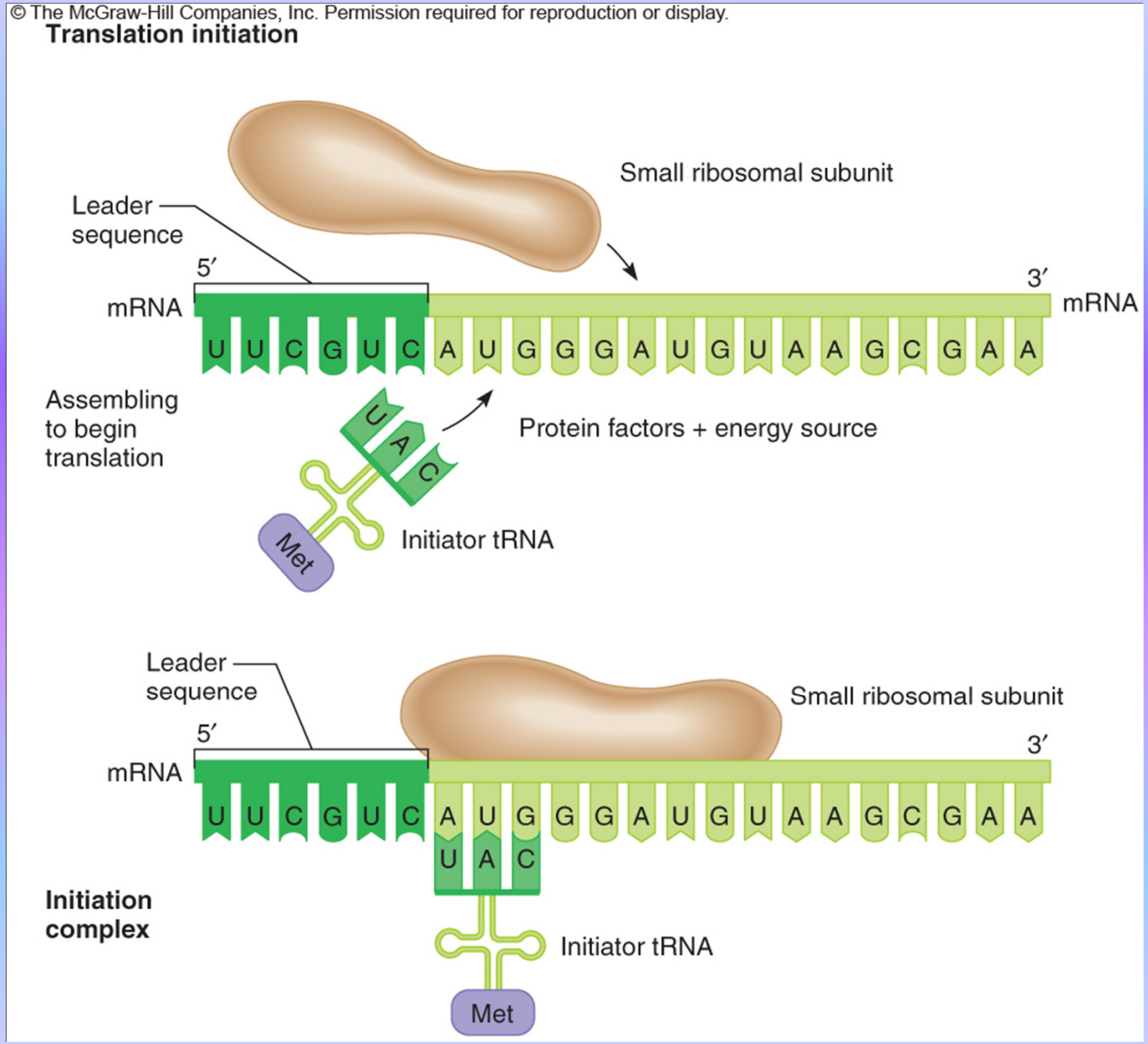
5. Degenerate

- Most amino acids are not uniquely specified
- ***Synonymous codons*** =
  - DNA triplets that specify the same amino acid
  - Often differ from one another by the base in the 3rd position
    - Called the "wobble" position
- Protects again mutation

Building a Protein

1. Translation Initiation

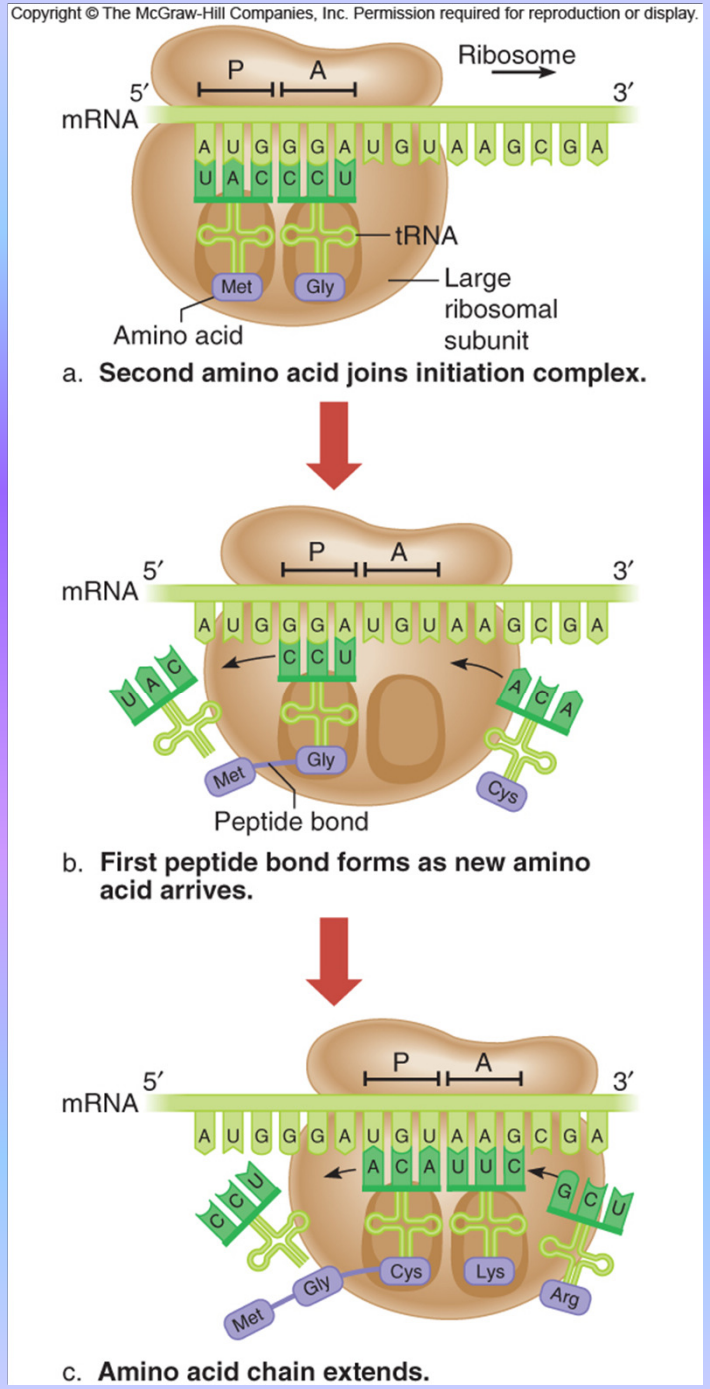
- Initiation complex forms
  - mRNA leader sequence joins small ribosomal subunit
  - mRNA “start” codon, AUG, attracts initiator tRNA carrying the amino acid methionine (Met)
    - Signifies the start of a polypeptide



2. Translation Elongation

- Large ribosomal subunit bonds to initiation complex
- Next mRNA codon bonds to its complementary ***anticodon*** =
  - 3 base sequence on one loop of tRNA molecule that is complementary to an mRNA codon and carries the appropriate amino acid
- P site holds growing amino acid chain
- A site next to it holds the next amino acid to be added to the chain
- ***Peptide bond*** forms between adjacent amino acids, creating a ***polypeptide chain***

Figure 10.16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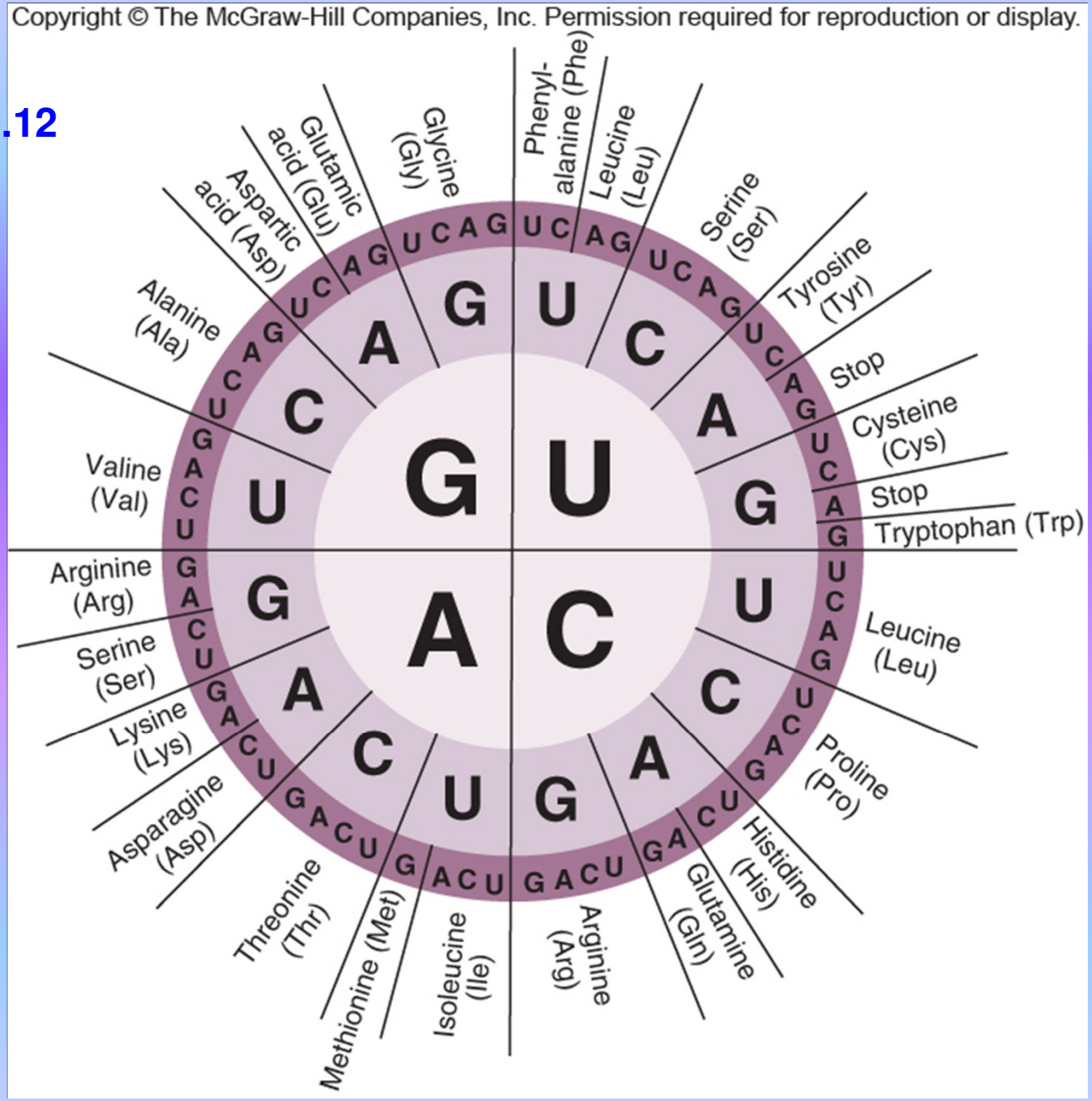
Ribosome
P
A
5′
3′
mRNA
A U G G G A U G U A A G C G A
U A C C C U
tRNA
Met
Gly
Large ribosomal subunit
Amino acid
a. Second amino acid joins initiation complex.
P
A
5′
3′
mRNA
A U G G G A U G U A A G C G A
C C U
U A C
A C A
Gly
Met
Cys
Peptide bond
b. First peptide bond forms as new amino acid arrives.
P
A
5′
3′
mRNA
A U G G G A U G U A A G C G A
A C A U U C
C C U
G C U
Gly
Cys
Lys
Met
Arg
c. Amino acid chain extends.

3. Translation Termination

- “Stop” codon reaches A site
- Ribosomal subunits separate
- New polypeptide is released

Figure 10.12



Let's Practice!

- mRNA

  AUGGGAUGUAAGCGAUAA

- mRNA codons

  AUG GGA UGU AAG CGA UAA

- tRNA anticodons

  UAC CCU ACA UUC GCU STOP

- Amino Acid (remember to use the codons!)

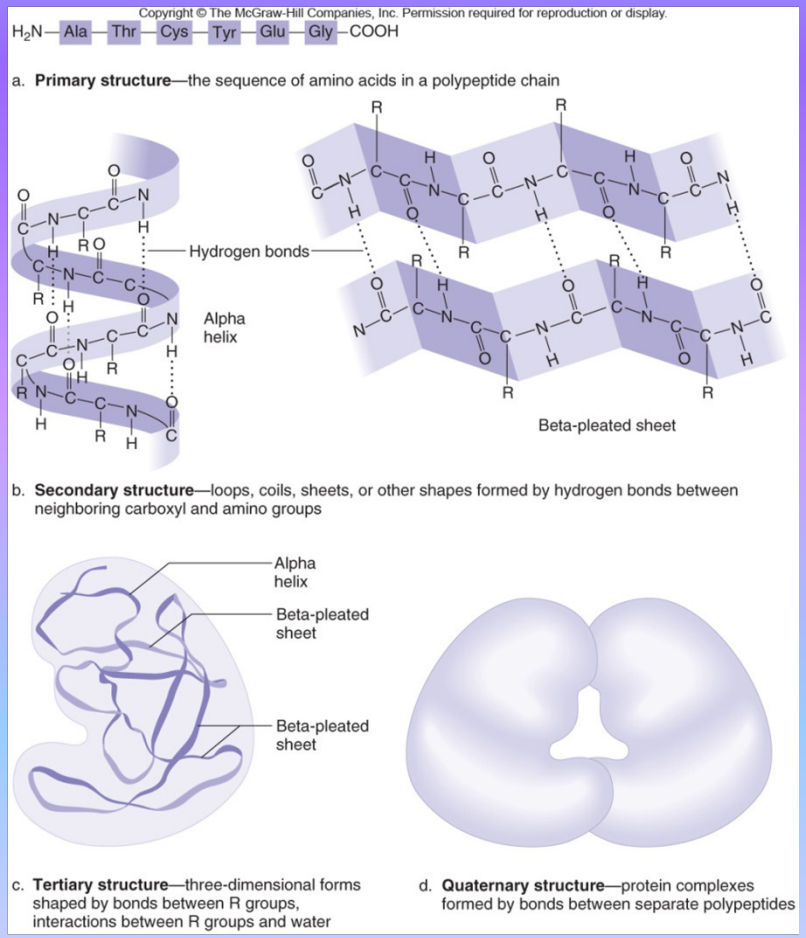
  Met Gly Cys Lys Arg

Processing a Protein

- Proteins fold into one or more 3-D shapes, or ***conformations***
  - Remember, shape affects function!
- Several levels
  - Primary (1°) structure
    - Amino acid sequence of a protein
  - Secondary (2°) structure
    - Forms loops, coils, barrel, helices, or sheets
    - Common examples
      - Alpha helix
      - Beta-pleated sheet

– Tertiary (3°) structure
  - Folds in a polypeptide caused by interactions between amino acids and water

– Quaternary (4°) structure
  - Protein that has more than one polypeptide subunit



- ***Chaperone proteins*** =
  - Binds a polypeptide and guides folding
- ***Proteasome*** =
  - Refolds or dismantles misfolded proteins
- Example of folding error:
  - Sickle cell disease
    - Red blood cells are bent out of shape